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Defensive Publications Series

June 19, 2018

MACHINE LEARNING FOR WIRELESS SOLUTION OPTIMIZATIONS: INTELLIGENT UE PAGING RETRY TIMER

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ABSTRACT

Dynamic changes in the behavior of Radio Access Nodes (RANs) require dynamic adjustment of core network's communication strategy with such RAN. The techniques presented herein specify a novel approach to dynamically calculate and adjust the paging retry timer on a radio access network, such as a 5G Mobile Network, in order to prevent excessive signaling on the radio access network causing unnecessary usage of valuable radio resources. The techniques presented herein leverage subscriber and RAN statistics to perform supervised time-series regression in order to calculate the optimal time the core network should wait before attempting to retry the paging message to a wider list of RANs.

DETAILED DESCRIPTION

Paging is a shared resource with a finite capacity in the radio access network. When a request for an idle mode access terminal is received by the Session Management function (SMF), the Access and Mobility Management Function (AMF) floods the paging notification message to all Access Nodes (ANs) (Radio Access Nodes) in the Tracking Area Indicator (TAI) List. A radio access network has several million customers and hundreds of ANs in the TAI. If each subscriber receives a page during peak network traffic hour, more than a million number of paging messages are generated per second. Various vendors have different implementations to avoid unnecessary signaling generated when each AN is paged on the network.

In these conventional implementations, the AMF typically attempts to page subscribers in multiple phases where, for example, the first phase is to page the AN to which the AMF believes, with a high confidence level, that the subscriber belongs. If the

AMF does not receive a response from the subscriber within a configured amount of time (e.g., t3413'), then the AMF expands its scope and attempts to page other ANs.

Operators often do not know what the correct timeout value (e.g., t3413') should be for the list of ANs belonging to each TAI. If the timeout value is set too high to cover congestions and other delaying factors (e.g., latency, remote cell location, *etc*.), then the timeout value may delay the entire procedure of finding a subscriber who may not be present at the AN paged in the first phase. Similarly, if the AN radio service is down or malfunctioning, and the AMF is not aware of it, then the AMF will still continue to page subscribers that were last seen on that AN. As such, the AMF will wait for t3413' to expire before attempting to find the subscriber at other ANs. However, if the timeout value is set too short, then the AMF starts flooding all the ANs and later finds out that the subscriber was present on the AN it paged in the first phase, but the AMF did not wait long enough before attempting to page the other ANs.

Additionally, with more usage of distributed architecture of 5G Node features, such as cell-splitting and sectoring, coupled with the auto-configuration of NodeB through self-organization networks (SONs), operators will continue to see ANs dynamically changing their behavior on the network. Such dynamic changes of AN behavior require dynamic adjustment of the core network's communication strategy with such ANs.

FIG. 1, below, shows illustrates an example in which an Access and Mobility Management Function (AMF) is not waiting long enough and, instead, causing excessive signaling to other Access Nodes (AN) when paging a subscriber (UE).

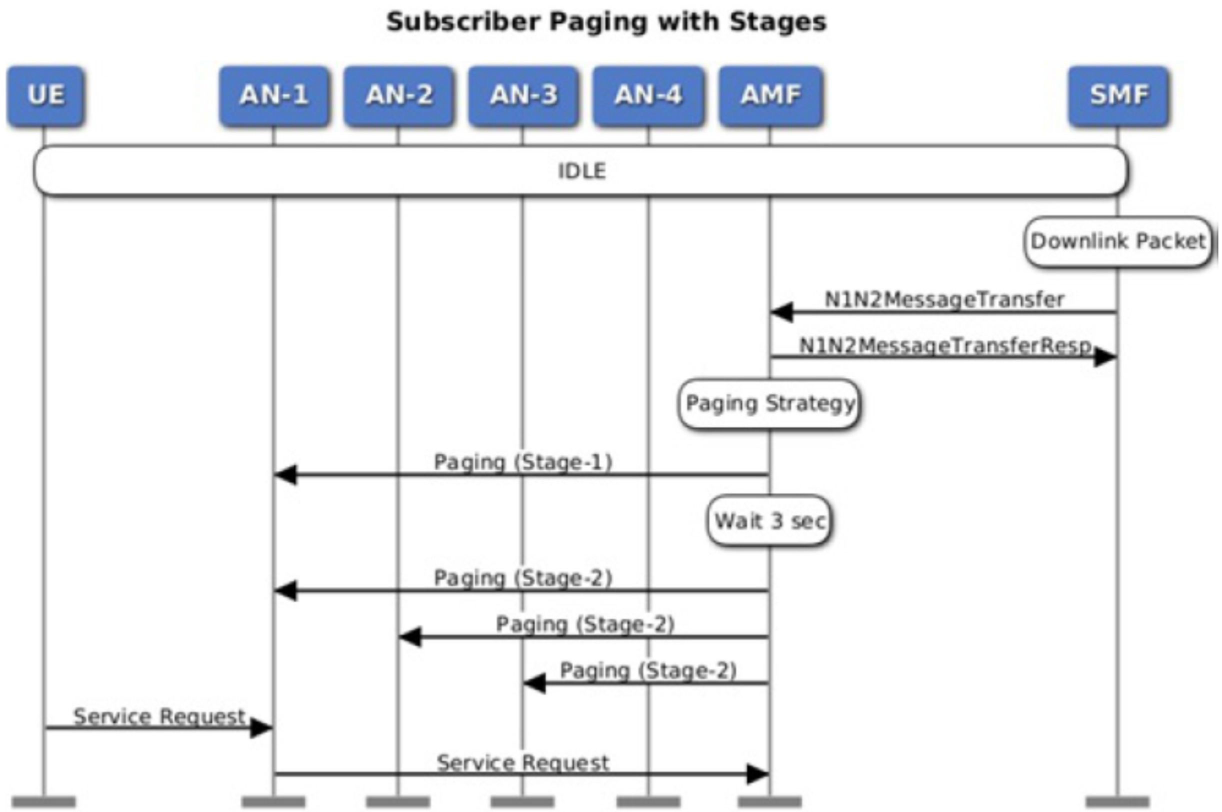

FIG. 1

FIG. 2, below, is a Network diagram below showing how various components are connected to each other and how Access Nodes (ANs) (Radio Access Nodes (R)ANs) are grouped together through Tracking Area Identifiers (TAI).

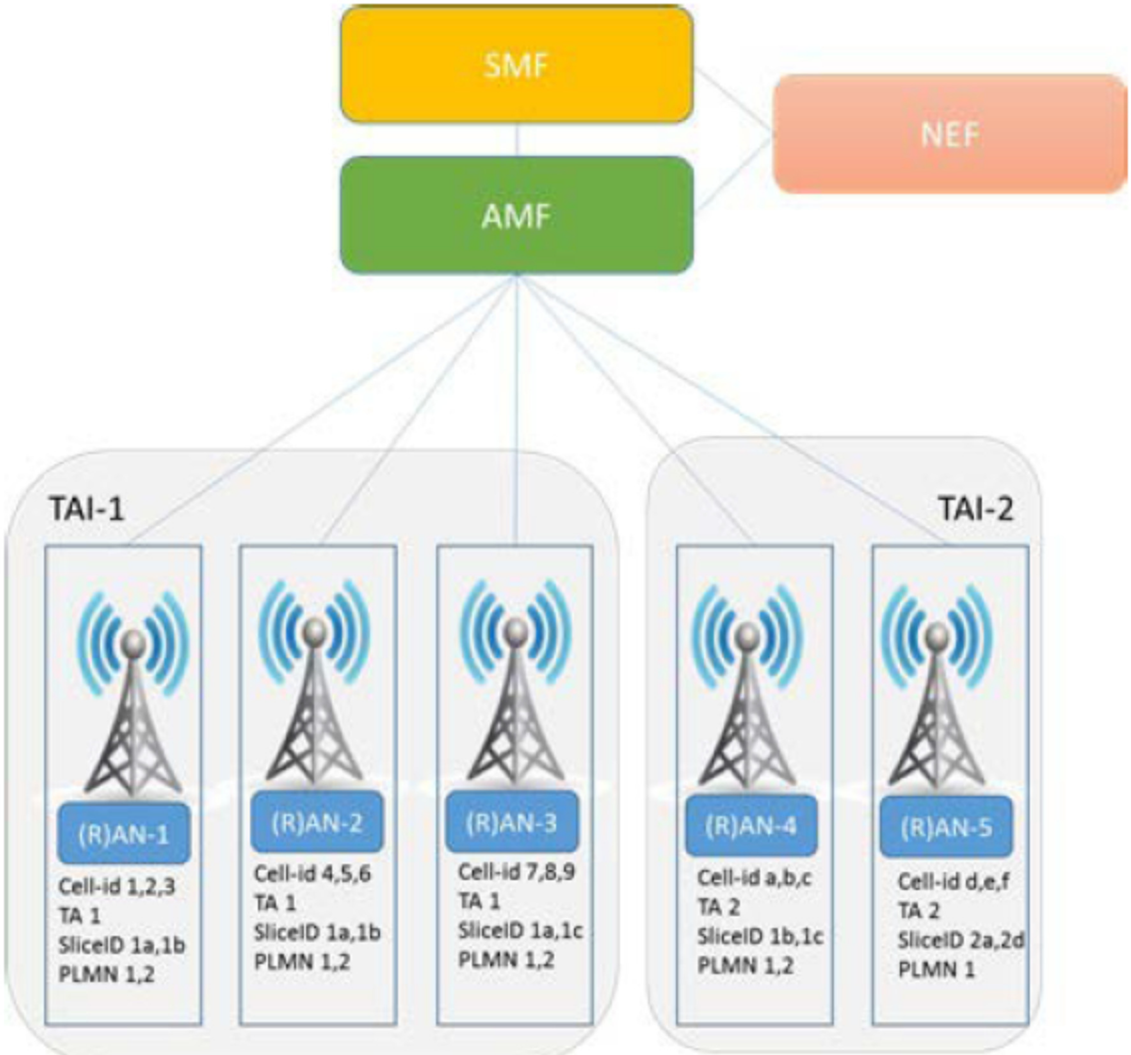

FIG. 2

Example Procedure Details:

Consider an example in which an AMF is setup to perform an optimized paging scheme where it uses a phase approach to first page a single or a small subset of ANs and to see if the paged subscriber responds from that small list of ANs. If the AMF does not receive a response from the paged AN or small list of ANs, then AMF moves on to the second phase and pages a larger subset of ANs.

In this example, when the AMF sends a paging request message for a subscriber, it should maintain a data structure containing the statistics associated with the paging message. These statistics include (Radio) Access Node Identifier (R)AN-ID, Tracking

Area Code (TAC), list of Tracking Area Identifier (TAI) list, sliceID, Paging Priority, Allocation Retention Priority (ARP), Data Network Name (DDN) and 5G QoS Indicator (5QI). The AMF also captures the time that the AMF sent that message to the AN and the exact time when it receives the response from the subscriber.

In addition, the AMF periodically transfers these statistics to Network Exposure Function (NEF) (e.g., every 5 minutes). The AMF also maintains a Timeout Mapping Table between the AN attributes and its paging retry timer (say t3413'). Initially this timer can be populated based on operator's input or default value. Table 1, below, illustrates one sample Timeout Mapping Table.

AN-ID	Slice ID	Paging Priority	ARP	DDN	5QI	PLMN	t3413'
1	1a	5	9	X	8	12345	3
1	1b	5	9	Y	8	12345	3
1	1a	2	1	Z	3	12345	2
1	1a	2	1	Z	3	12345	2

Table 1

The NEF also processes the statistics (provided by the AMF, above) and performs a time series based Supervised Multi-Variant Autoregressive algorithm to determine the best t3413' timeout value. Once the NEF has a new timeout value available, it sends that value to the AMF so that the AMF can dynamically update its Timeout Mapping Table. The next time that the AMF pages a subscriber, the AMF uses the latest timeout value present in the Timeout Mapping Table.

If NEF receives sufficient samples to believe that none of the subscribers paged on a particular AN are responding from that AN, then the NEF sets the timeout value of that AN to 0. This will indicate to the AMF that the AMF should directly move to the second stage of paging where the AMF will page a subset of AN instead of just a single AN.

FIG. 3, below, illustrates subscriber paging with stages and a dynamic timeout update as described herein.

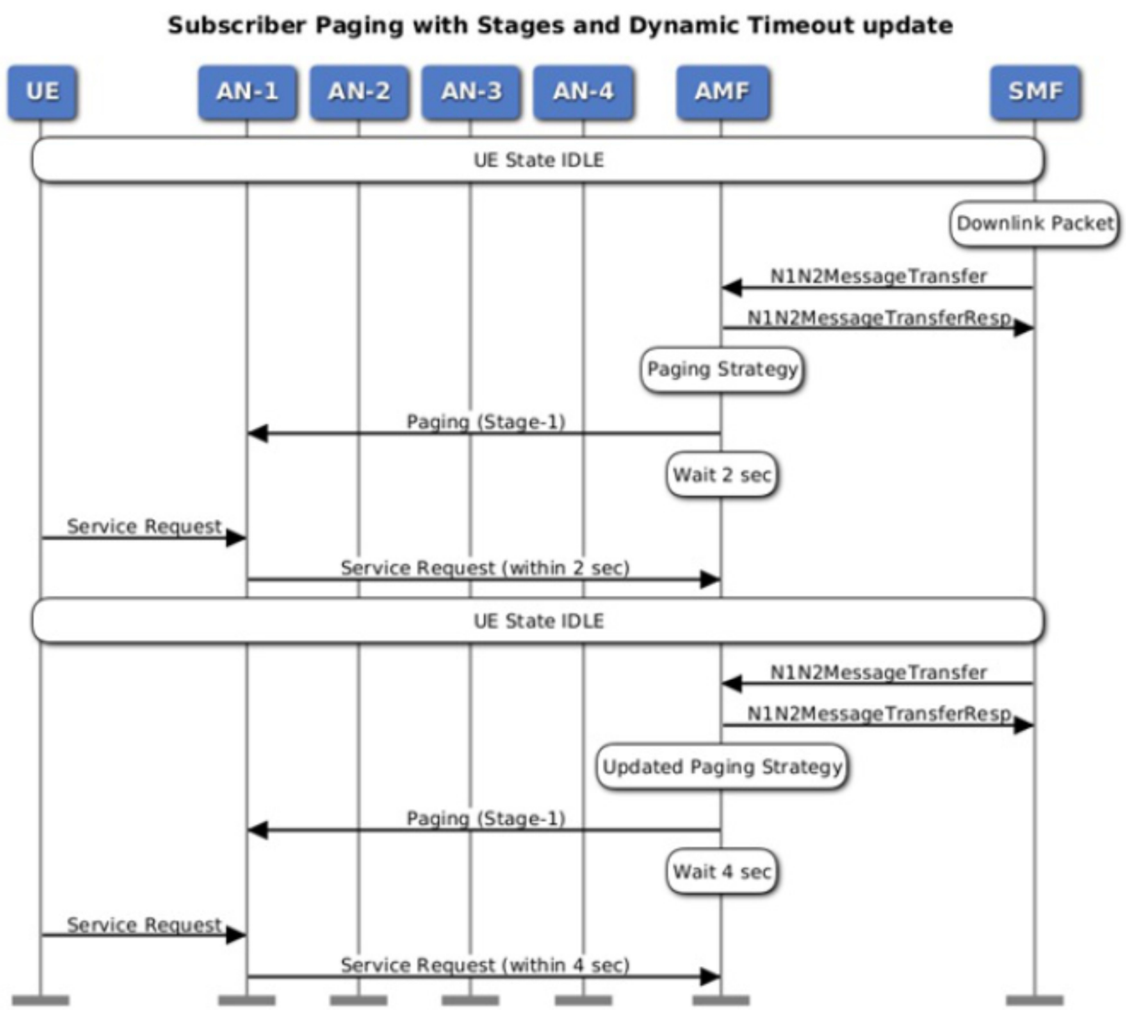

FIG. 3

Supervised Multi-Variant Autoregressive Model:

As noted above, certain operations presented herein involve a Supervised Multi-Variant Autoregressive algorithm to determine the best t3413' timeout value. FIG. 4, below, illustrates several operations associated with use of a Supervised Multi-Variant Autoregressive algorithm.

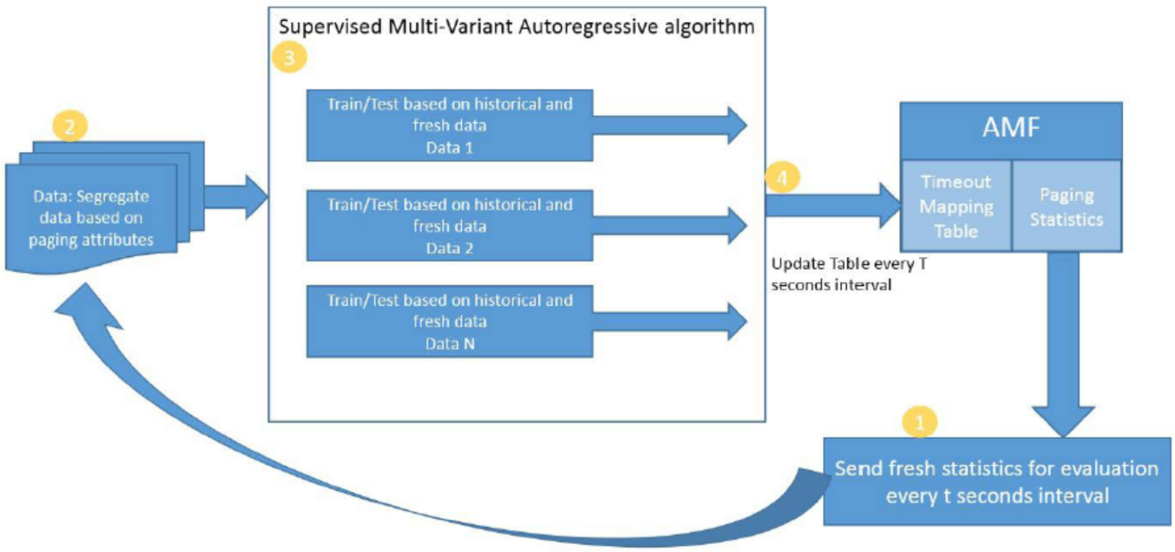

FIG. 4

More specifically, at (1) shown in FIG. 4, the NEF receives the paging statistics from the AMF at a periodic interval (e.g., every t seconds). At (2), once the NEF receives the statistics, the NEF segregates the data based on one or more paging attributes (e.g., sliceID, Paging Priority, ARP, DDN, 5QI, *etc*.). At (3), a time-series based Auto-regressive algorithm is applied on the fresh segregated data combined with the historical data in order to forecast the most optimal paging response time. At (4), the NEF then periodically sends the results back to AMF which updates its Timeout Mapping Table (See Table 1, above, as a sample).

In summary, when a subscriber is paged, it is critical to know the expected time that the subscriber may take to respond before the paging message is broadcasted to additional Access Nodes. The subscriber's expected time to respond can vary depending on, for example, the type of devices, the condition of access nodes, *etc*. In addition, with the usage of the distributed architecture of 5G NodeB, features such as cell-splitting and sectoring, and the auto-configuration of NodeB through self-organization network, will continue to result in Access Nodes dynamically changing their behavior on the network. Dynamic changes in the behavior of Access Nodes requires dynamic adjustment of core network's communication strategy with such Access Nodes as well. The techniques presented herein specify an approach to dynamically calculate and adjust the paging retry timer on 5G Mobile Network based on the Access Node behavior so that the unnecessary signaling to Access Nodes can be prevented. In particular, as detailed above, the techniques presented herein leverage subscribers and radio access node statistics to perform supervised time-series regression in order to calculate the optimum time the core network should wait before attempting to retry the paging message to a wider list of radio access nodes.